THIN FILM SOL-GEL DERIVED GLASS

REFERENCE TO RELATED APPLICATIONS

This application is related to a companion application Serial No. _____ (IOS-118), filed on even date herewith and assigned to the assignee of the present application.

FIELD OF THE INVENTION

This invention relates to a process for producing photosensitive thin films of sol-gel derived glass and to such films of a thickness useful for integrated optic devices produced thereby..

BACKGROUND OF THE INVENTION

The doctoral thesis by the applicant herein entitled "Photolithography of Integrated Optic Devices in Porous Glass, City University of New York, 1992 describes an organometallic system of inclusions in a thermally-assisted, porous glass bulk material. The process for fabricating the glass requires introduction of a photosensitizer, exposure to light through a mask and two heat treatments. The doctoral thesis states that sol-gel techniques can be used to make the porous glass bulk material.

BRIEF DESCRIPTION OF THE INVENTION

The invention is based on the realization that the porous glass techniques for bulk materials using thermally assisted, organometallic, sol-gel derived glass can be extended to thin films suitable for telecom components and virtually free of lateral shrinkage. Consequently, a variety of highly desirable integrated optic components can be made by such a technique. Specifically, a technique for the photolithographic fabrication of integrated optic structures in thin films of photosensitive sol-gel glasses is described here.

This technique involves the formation of a photosensitive sol-gel thin film including an organometallic photosensitizer, on a suitable substrate (glass, silicon, or any other support material). Next, the photosensitive film is exposed to white or ultraviolet light inducing a photochemical reaction in the photosensitive sol-gel glass network with the end photo-product being a metal oxide. The photodeposited metal oxide is permanently bound to the sol-gel film glass network as a glass modifier during a heat treatment process, which in turn induces a permanent refractive index increase in the glass. The refractive index increase is dependent on the concentration of the photosensitizer and on the light energy used in the exposure process. Therefore, a spatially varying light intensity during exposure results in a spatially varying refractive index profile. This refractive index profile induced in the film can be designed to guide light.

Exposure of the photosensitive sol-gel film to white or ultraviolet light induces the unbinding of the metal from the photolabile moiety component of the photosensitizer followed by the binding of the metal to the sol-gel film. The exposed regions of the sol-gel film are converted to a metal oxide silica film by first and second step heatings at a low temperature and high temperature, respectively. The low temperature drives out the unexposed (unbound) photosensitizer and the unbound photolabile moiety. The higher temperature step unbinds the organic component from the bound photosensitizer and drives it off. This step also permanently binds the metal to the silica film forming a metal oxide glass modifier. If the sol-gel film is deposited on a glass or silicon substrate, a metal oxide doped silica region of Si-O-M-O-Si ~~is~~ formed in the exposed regions acting as a glass modifier which in turn modifies the refractive index. The unexposed photosensitizer is driven off during the heat treatment steps. Since no material is

removed from the sol-gel film in this process, as in the case of prior-art processes, the resulting top surface is planar, thus leading to a simpler process for producing devices and for achieving increased lifetime of resulting devices.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig's. 1, 2, 4 and 5 are schematic side views of thin films in accordance with the principles of this invention; and fig. 3 is a block diagram of the steps for fabricating a structured thin film in accordance with this invention.

DETAILED DESCRIPTION OF THE INVENTION

Fig. 1 is a side view of a film 11 of a sol-gel film with R-M-X constituents dissolved therein. The film is shown formed (usually by a well known spinning technique) on the SiO_2 surface layer 12 on a silicon substrate 13. The R constituents are taken from a class of volatile organic materials consisting of CH_3, CH_3-CH_2, CH_3-CH_2-CH_2, the M constituents (metals) are taken from the class of metals consisting of group IVA metals Ge, Sn and Pb, Group VI including Se and Te, Group VIII including Fe, Cu, Ni, and Group IVB including Ti and Zn and the X constituents (photosensitizers) are taken from the class consisting of chlorine, iodine, fluorine, bromine, and carbon.

Fig. 2 shows an alternate embodiment where the sol-gel film 20 is formed on a glass substrate 21. Fig's. 1 and 2 represent the initial sol-gel solution formed on appropriate substrates of silicon (fig. 1) and glass (fig. 2). The process of forming the sol-gel solution into useful film structures is discussed in connection with fig. 3.

Specifically, fig. 3 is a block diagram of the process for fabricating structured films from the sol-gel solution of fig's. 1 and 2. Block 31 of fig. 3 represents the step of

forming a sol-gel film with inclusions of R-M-X on a suitable substrate (as shown in fig. 1 or fig. 2). Block 32 represents the exposure of the film through a mask to light in a range of wavelengths from ultraviolet (UV) through the visible range. This step unbinds the photosensitizer (X) and binds the metal (M) to the silicon oxide.

Block 33 of fig. 3 represents the step of heating the film to about 300 degrees C for a time to bind the metal permanently to the SiO_2. Block 34 of fig. 3 represents the final heating step to about 900 degrees C for driving off the metal and the photosensitizer from unexposed regions of the film.

Fig. 4 shows the structure of fig. 1 with a mask 40 in place. Mask 40 is opaque to the incident light (arrow 41) in regions 42 and 43 and is transparent to light in region 44. The result of exposure to light is a structured film (in excess of 1 micron) where the exposed region of the film includes Si – O – M – Si and the unexposed regions include SiO_2.

The concentration of photodeposited metal oxide determines the index of refraction of the exposed region which can be made relatively high compared to that of adjacent regions. If we visualize region 44 extending away from the viewer as indicated by the broken lines in fig. 5, the resulting structure can be seen to represent a waveguide with the "core" being buried as indicated.

In one specific embodiment, a sol-gel film 1 - 10 microns thick was formed on a silicon substrate 1 cm x 0.5 cm x 0.1 cm thick with a SiO_2 surface layer < 2 microns thick thereon. The sol-gel film included Sn (M) 2% I (X) 2 %, and $(CH_3)_3$ (R) 2%. Region 44 has a width of 10 microns, exposed to light with a wavelength of 254 nm for 30 minutes. The exposed region had an index of refraction of 1.55 and the unexposed

regions had indices of refraction of 1.45. The film has a thickness of 1 – 10 microns after processing and has unchanged lateral dimensions.

In another embodiment, a sol-gel film 1 – 10 microns thick was formed on a glass substrate 1 cm x 0.5 cm x 0.1 cm thick. The sol-gel film included Ti (M) 2% Cl (X) 4%, and Cp (R 4% where Cp is cyclopentadienyl. Region 44 has a width of 10 microns, exposed to light with a wavelength of 5.14 nm for 120 minutes. The exposed region had an index of refraction of 1.75 and the unexposed region had indices of refraction of 1.45. The film had a final thickness of 1 – 10 microns with the lateral dimensions thereof being unchanged.